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by

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Abstract

This paper analyses the association between inter-firm collaborative agreements and the technological capabilities of the largest European electronics firms between 1984 and 1997.
To this purpose we collected information about 2,240 R&D agreements sponsored by the EU and 1,970 non sponsored agreements signed by the sample firm. We classified agreements into fourteen industrial sectors by using cluster analysis.
Moreover, we selected the most important fourteen technological classes for the sample firms in the period 1984-1996 and for each class calculated the sample firms' share in world patent applications. We analysed the effects of agreements on firms' technological capabilities measured by patent shares.
Our analysis shows that non-sponsored agreements have significant effects on the technological capabilities of the firm. However, only agreements with extra-European (US and Japanese) partners produce significant effects on the technological capabilities of the firm. Finally, EU-sponsored agreements have insignificant effects on technological capabilities. These results indicate that there is a weak complementarity among European electronics firms and suggest that a reshaping of EU policies towards collaborative R&D is required.

Key words: inter-firms alliances, innovation, technological capabilities, electronics
JEL: L21, O32, O38, L63

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1. Introduction[1]

This paper analyses the accumulation of technological capabilities of large European firms operating in the information and communication industries (computers, telecommunications equipment, semiconductors and consumer electronics) (ICT).

The position of Europe in these sectors is weak compared with the US and Japan. This is clearly shown by the share of total US patenting in the following technological classes: electronic capital goods and components, telecommunications equipment and consumer electronics. With few exceptions (such as Thomson-CSF in electronic components and Siemens and Philips in telecommunications) the share of European firms among the world larger innovators is small and declining between 1969 and 1990. Technological specialisation of European firms in these technologies is also weak and declining (Patel and Pavitt, 1994). However, more recently, new European firms have reached the technological frontier in these sectors (e.g., Nokia and Ericsson in mobile communication).

The European firms operating in the information and communication industries (ICT) sectors have tried to catch up with the US and Japanese world leaders by relying on both in-house R&D and R&D collaborations. The economics literature has pointed out many potential benefits of R&D collaborative agreements: risk sharing, exploitation of economies of scale and scope, reduced duplication of research efforts, access to complementary assets and reduction of time to market (Teece, 1986; Jorde and Teece, 1990). Through R&D (including joint R&D) firms may also improve their ability to monitor, absorb and exploit external knowledge (Cohen and Levinthal, 1989; Rosenberg, 1990).[2]

Since the 1980s, the European Commission has supported R&D in the ICT sectors, especially joint R&D. While EU policy aims to stimulate innovation and to enhance the capabilities and competitiveness of the European industry overall, the ICT sectors have received a particular

[1] An erlier draft of this paper was prepare for the "Dynacom" TSER Project, EC DGXII (contract no. SOE1-CT97-1078). We would like to thank Andrea Ala and Sandro Sergiacomo for their contribution to data collection. We also thank Piero Cavaleri for his suggestions on the design of the database and Pari Patel for providing us with patent data collected at SPRU. Finally, Giovanni Dosi, Mike Hobday and Ed Steinmulluer have provided useful comments on earlier drafts of the paper.
[2] Another dimension of the relationship between innovation and agreements is represented by the effects of firms' innovative capabilities (generic or context-specific) on the ability to set up linkages with different organisations

attention by the European Commission. This is mainly because the innovative activities of these sectors are expected to be "pervasive", i.e., they should yield significant potential spillovers for many other sectors (CEC, 1993 and 1995).

What are the implications of EU-funded R&D programmes for the technological performance of ICT firms themselves? Given the small amount of EU-supported R&D as a share of total R&D expenditures of large European firms, we do not expect much direct effect on the technological performance of these firms. However, we examine whether these effects vary between EU-sponsored agreements in the firms' core sector versus agreements outside the core sector. Moreover, we ask whether these publicly supported agreements produce effects similar to that of non-sponsored alliances.

In order to address these issues this paper analyses the agreements of the largest 15 European electronics firms listed in Fortune 500 between 1984 and 1997. The paper compares EC-supported agreements with non-sponsored alliances undertaken by the sample firms. Moreover, the effects of sponsored and non-sponsored agreements on the firm technological performance are analysed in fourteen sectors. We use as indicator of technological performance the number of patents filed by the firm in each of these sectors as a share of the total World patents in the same sectors.

The paper is organised as follows. Section 2 provides a brief discussion of the literature on R&D alliances. Section 3 illustrates some description of the data and Section 4 analyses the effects of inter-firm agreements on the technological capabilities of the sample firms. Section 5 closes the paper.

2. The literature and the research hypotheses

Rapid technical change, the convergence of industries, and the rising internationalisation of markets spur firms' restructuring and growth, through M&As and strategic partnership (see, among others, Mytelka, 1995). The implications of inter-firm alliances for the R&D of the firm have been debated in the literature. Some scholars argue that such agreements stimulate

(customers, competitors etc.) (Malerba and Torrisi, 1992).

opportunistic behaviour and R&D under-investment because of information asymmetries (Katz and Shapiro, 1985). Moreover, R&D alliances may give rise to problems of appropriability, information asymmetries, and coordination failures which increase transaction costs (Pisano, Russo and Teece, 1988; Porter and Fuller, 1986; Bleeke and Ernst, 1992).

On the other hand, other scholars point out that R&D collaborations increase the private incentives to conduct R&D and, therefore, to correct the imperfections in the market for knowledge (Baumol, 1990). More precisely, the main benefits of R&D collaborative agreements are represented by risk sharing, exploitation of economies of scale and scope, reduced duplication of research efforts, access to complementary assets and reduction of time to market (Teece, 1986; Jorde and Teece, 1990). Finally, another reason for undertaking R&D collaboration is that firms may acquire new capabilities and improve their ability to monitor, absorb and exploit external knowledge (Cohen and Levinthal, 1989; Rosenberg, 1990).

The empirical evidence shows that the number of international R&D alliances has grown at an annual average rate of 10.8% between 1980 and 1994, and the percentage of R&D agreements has recently reached 10-15 per cent of all agreements (Narula and Hagedoorn, 1998). There is also evidence of a relative growth in the use of non-equity agreements (strategic alliances) compared with equity alliances (such as joint ventures) (Hagedoorn, 1996). This can be explained by the fact that strategic alliances require less fixed costs than JVs and probably reduce the conflicts between partners that stem from problems of reconciling rent-sharing and different time horizons. Moreover, EU firms tend to engage in R&D alliances in sectors where they have not comparative advantages. Finally, in the 1990s non-subsidised agreements among European firms have dropped while those between European firms and US firms have increased (Narula and Hagedoorn, 1998).

Given that firms, particularly those operating in high tech sectors, rely increasingly on international R&D collaboration, why then should the EU sponsor R&D collaborations among European firms? One reason is the stimulation of collaboration among European firms to help them to reach a minimum efficient scale of R&D operations and to reduce the technical gap with the US and Japanese leaders[3]. The first generation of EU-sponsored programmes launched between 1984 and 1988 has probably helped European firms, especially small firms, to gain access to complementary capabilities or join international networks. These EU-sponsored projects were pre-competitive, fell within the core business areas of the participating firms and focused on niche technologies (Mytelka, 1995).

In subsequent years, the EU has favoured joint R&D which aims to the development of "useful" technologies, closer to market needs. But this raises the question of why the EU is subsidising R&D activities that firms would probably conduct in any case, given the proximity of the research with market needs. A rationale for this type of EU intervention is that the development of applications in new fields such as electronic commerce requires high costs associated with investments in quasi-public goods (e.g., network facilities and training) and brings about a high risk of failure because the information about the benefits of these applications is limited and both users and producers of these applications can be locked into an inferior technology. A lack of co-ordination between users and producers of these new applications then could give rise to a market failure that the policy-maker can correct by subsidising joint R&D that involve users. The problems of co-ordination are particularly significant in Europe, because of linguistic, cultural and institutional barriers across countries. It is worth noting that a large share of alliances analysed in this paper concern user-producer relationships (e.g., electronics equipment firms and chemicals or automobile manufacturers) where such co-ordination problems are expected to occur.

A key question is whether EU-sponsored agreements have really helped European firms to coordinate their R&D efforts, to exploit potential synergy and to reduce substantially the gap with their US and Japanese counterparts.

A recent study on the semiconductor industry shows that, despite the EC support to infra-European R&D collaboration, European firms have continued to rely mostly on collaborative linkages with US or Japanese companies, which still represent their main source of technology (Hobday, 1997). According to Hobday, this suggests that the EU programmes did not affect the technological strategy of European firms. Moreover, the pattern of international R&D agreements of the European semiconductor firms between 1980-84 and 1985-1991 suggests that these firms shifted from passive forms of technological agreements to more active forms (Hobday, 1997). This evolution in the patterns of technological agreements may indicate a

[3] The stimulus of cooperation is often mentioned in the literature (see, for instance, Folster, 1995).

growth in technological capabilities of the European firms. The evidence provided by Hobday does not clarify to what extent this improvement of capabilities depends upon the participation in joint R&D programmes sponsored by the EU or whether it is due to other factors (in-house R&D and learning associated with non-sponsored agreements). Our paper aims to test this hypothesis and to accomplish this purpose we compare the patterns of EU-sponsored agreements with non-sponsored agreements and their implications for the technological performance of the firm. Moreover, unlike earlier works we adopt a measure of technological performance, which is the share of a firm's patent applications in the total world patent applications in different technological fields.

3. The empirical analysis

3.1. Data and methodology

We have selected the largest European electronics firms listed in 1997 Fortune 500. For these 15 firms we collected information, from the CORDIS database, on the participation in the EU programmes centred upon ICT (e.g., ACTS, Advanced Communications Technology and Services, ESPRIT, European Strategic Programme of Research in Information Technology, TELEMATICS, and Eureka) (CORDIS, 1998). Between 1984 and 1998 the sample firms were involved in 2,240 R&D agreements with more than 5,000 partners. It is worth noting that although in theory non-European firms are allowed to take part into EU-subsidised R&D programmes, we found only seven US partners and one from Japan.

After elimination of inconsistencies and errors in the original database, we structured a qualitative data set which contains the following information for each project: the starting date, the partners involved and their respective home countries, and the main industrial sector (we assigned each project to a four-digit industry by using the US Standard Industrial Classification, 1987 revision).

Moreover, we collected information on over 1,970 non-sponsored R&D agreements (JVs, licensing agreements and other R&D or technology-related agreements) undertaken by the sample firms during the period 1984-1997. The database called ARGO contains information about events (agreements, growth operations, and corporate reorganisations) reported in a large set of trade journals, magazines and other specialised press. Events information was drawn from IAC's Insite Promt database (http://www.insitepro.com) for the period 1993-1998. We have collected similar information for the period 1984-1992 from Predicasts F&S Index database. We also collected information about the number of subsidiaries by industrial sector from Dun & Bradstreet's Who Owns Whom database for the year 1983. Finally, we collected information about the technological performance of the sample firms between 1970 and 1996. The technological performance of the firm is measured by US patents as classified by SPRU, University of Sussex.

In order to analyse the effects of agreements on technological capabilities we classified both agreements and capabilities in 14 broad sectors. This aggregation has also the advantage of yielding results which are relatively easy to interpret.

Patent data were grouped into 14 technological sectors by using the SPRU 34 technological classes (see Table A.1 in the Appendix). The 14 sectors reported in Table A.2 in the Appendix represent the largest single sectors among the SPRU 34 classes. Overall, they account for more than 47,000 patents or about 90 per cent of the sample firms' total patents between 1970 and 1996.

As far as agreements are concerned, we obtained 14 sectors by means of cluster analysis. To this end we drew from the IAC Promt database all the articles which report on all strategic alliances, licensing agreements, M&As, and new subsidiaries occurred in selected countries in 1998.[4] The articles were in total 36,451.

IAC's Insite Promt database attaches to each article one or more four-digit SIC codes to identify the sector (s) involved in the article. This information allows us to calculate how many times two distinct SIC sectors are jointly reported in the sample articles. This leads to 3,568 pairs of four-digit sectors and 6,748 joint frequencies on 627 different 4-digit sectors.

[4] The countries selected are the United States, Japan, Germany and India, because they arise as the most important countries in our database from 1993-97. Among 11,905 selected events in our database, 10.555 (88%) include at least one of these countries.

To simplify, we focused on 3-digit sectors and obtained 109 pairs of sectors on 227 different 3-digit sectors.[5]

Since the sample firms have been involved in only 129 3-digit sectors between 1984 and 1997, we focused our analysis on these 129 sectors, which give rise to 5,940 joint frequencies. We then used these data to obtain 14 groups of related sectors through cluster analysis. The clusters obtained by using the centroid method and cosine similarity distance maximise the variance between groups while minimising the variance within groups.

Tables A.3 in the Appendix shows the 14 clusters and Table A.4 shows the 3 digit SIC codes associated to each cluster. For each 3-digit SIC code the number of links with other 3-digit SIC codes in the same cluster is indicated.

3.2 Preliminary analysis

We classified the collaborative agreements stipulated by the sample firms into two categories:

- Private agreements- AG (technological joint ventures and strategic alliances);
- EU sponsored agreements - CORDIS.

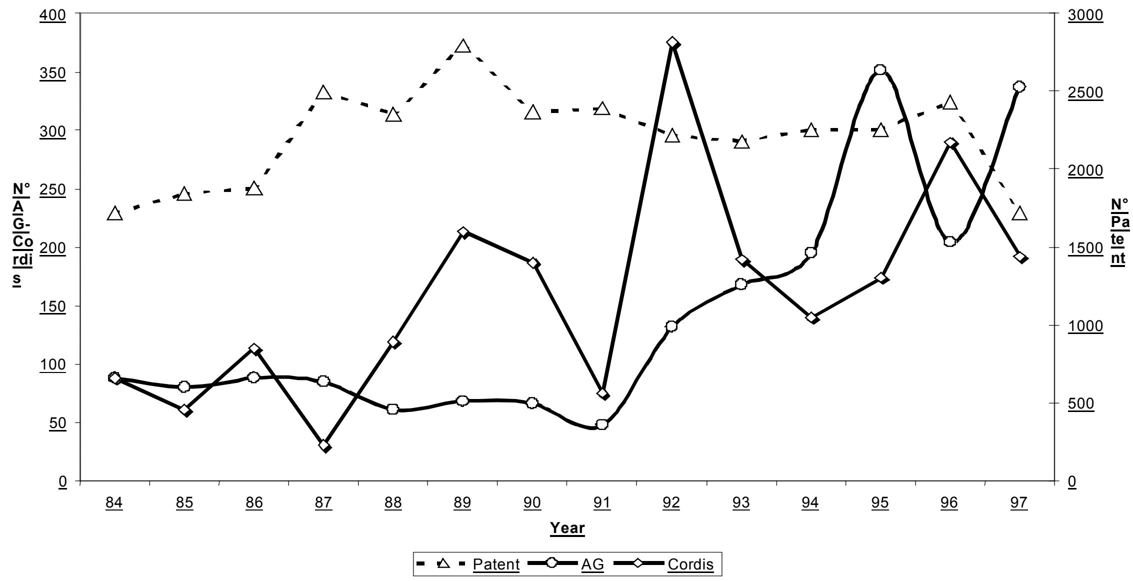
Table 1 and Figure 1 show the evolution of agreements and patents of the sample firms as a whole. The increase of AG in the 1990s showed by our data is in line with earlier empirical studies (Hagerdoorn, 1996).[6] Also CORDIS agreements increases over time.

Table 1: Patents and agreements

Year	84	85	86	87	88	89	90	91	92	93	94	95	96	97	Total
AG	88	80	88	85	61	68	66	48	132	168	195	351	204	337	1971
CORDIS	88	61	113	30	119	213	187	75	375	189	140	174	290	192	2246
Patents	1717	1846	1879	2496	2353	2792	2366	2390	2219	2178	2255	2254	2429	-	29147

Figure 1: Evolution of agreements and technological performance

[5] Obviously, the number of matches observed are much smaller than the theoretical matches. The theoretical combinations of N (N=129) 3 digit SIC sectors taken 2 at a time is C=N!/[2!(N-2)!]=8,256.This difference is due to the fact that our firms are active in a relatively limited number of sectors.
[6] Note that ICL and Nixdorf have been taken over by Fujitsu and Siemens respectively. These two firms have been considered separately even after the acquisition. Post-acquisition data have been drawn from their respective non consolidated balance sheets.



Technological capabilities

Patents are a fairly good proxy for technological capabilities of the firm. Even though in some technological fields, such as software, patents are not used as an instrument to protect inventions, they represent indicator strongly correlated with other measures of technological efforts such as R&D expenditure (Griliches, 1990). Moreover, patent represent the most codified part of a firm technological knowledge. Technological capabilities, which are a source of sustained competitive advantage for the firm, rely on both codified knowledge (to the extent that this can be protected by intellectual property right) and tacit knowledge and organisational routines, which cannot be patented but are difficult to replicate and imitate (Barney, 1991). This limitation notwithstanding, however, patents are the most reliable instrument to measure the diversification of technological activities. Alternative measures such as the classification of R&D expenditures by line of business are only available for US firms. Moreover, also R&D-based measures have their limitations, including the classification criteria adopted, which are based on industrial classification (SIC) rather than technological classification (e.g., IPC).

Our data show that patents applications of the sample firms overall increased significantly in the second half of the 1980s and remained stable (if not decreased) afterwards. The only exceptions to this trend are Nokia and Ericsson, whose patent applications increased steadily over the period examined.

Table 2 shows the relative importance of each sector in the firms technological and business activities. The sectors where most of the sample firms' technological activities were centred before 1984 are Telecommunication equipment (class 6), Instruments and Controls (class 4), Electrical Devices and System (class 7) and Image and Sound Equipment (class 5). These four sectors represent overall about 48% total patents (note that patents do not measure competencies in software). [7]

Table 2: Sector statistics

	Variables (shares)				
Sector/ Technology	**CORDIS(84-97)**	**AG (84 –97)**	**1983 subsidiaries**	**SPRU classes**	**share in total patents (1969-83)**
1	0.009	0.046	0.046	18	0.021
2	0.005	0.001	0.01	16	0.029
3	0.034	0.048	0.205	14	0.083
4	0.065	0.035	0.179	30	0.124
5	0.007	0.07	0.005	28	0.095
6	0.249	0.307	0.055	24	0.17
7	0.015	0.06	0.044	26	0.098
8	0.099	0.146	0.013	27	0.088
9	0.279	0.116	0.026	9	0.014
10	0.173	0.118	0.032	25	0.06
11	0.015	0.019	0.019	33	0.009
12	0.023	0.003	0.001	4	0.029
13	0.01	0.015	0.019	13	0.043
14	0.016	0.011	0.325	31	0.015
Total	0.999	0.995	0.979		0.878

Tables 3 and 4 show substantial differences across the sample firms in the patterns of technological activities measured by US patent applications. As expected, Siemens and Philips appear as the most diversified firms; Ericsson and Racal show a marked concentration of technological activities in telecommunications. Finally, it is worth noting the increase in R&D intensity (R&D/sales) for Ericsson and Nokia.

Table 3: Technological Diversification (US patents)

Firm	Herfindahl	Specialisation Ratio	Main Sector	RTA

[7] See Tables A.1 and A.2 in the Appendix for patent classification and the most important technological classes for the sample firms.

	1984-90	1991-96	1984-90	1991-96	1984-90	1991-96	1984-90	1991-96
ABB	0.135	0.139	0.169	0.194	18	18	0.941	0.967
Alcatel	0.170	0.221	0.351	0.426	24	24	0.790	0.805
Bull	0.251	0.487	0.483	0.703	27	27	0.816	0.816
EMI	0.169	0.166	0.195	0.215	26	25	0.699	0.671
Ericsson	0.260	0.474	0.475	0.677	24	24	0.840	0.873
GEC	0.181	0.178	0.303	0.331	18	30	0.825	0.619
Nokia	0.210	0.286	0.263	0.524	24	24	0.729	0.839
Philips	0.145	0.153	0.227	0.258	25	28	0.660	0.631
Racal	0.298	0.303	0.494	0.446	24	24	0.846	0.813
Schneider	0.258	0.246	0.418	0.359	24	26	0.821	0.794
Siemens	0.137	0.118	0.194	0.184	18	18	0.694	0.842
Thomson	0.155	0.207	0.235	0.402	24	28	0.705	0.746
Average	0.197	0.248	0.317	0.393			0.781	0.785
s.e.	0.056	0.122	0.085	0.121			0.057	0.071

Table 4: Firm sales and R&D Expenditures ($ millions)

Firm	Sales		R&D Expenditure		R&D/Sales	
	1984-90	1991-96	1984-90	1991-96	1984-90	1991-96
ABB	18974	30231	1540	2468	0.08	0.08
Alcatel	17232	30347	1497	2019	0.09	0.07
Bull	3689	5177	391	372	0.11	0.07
EMI	4943	6617	77	30	0.02	0
Ericsson	5183	12849	683	2039	0.13	0.16
GEC	8889	9953	1042	837	0.12	0.08
ICL	1293	2243	222	97	0.17	0.04
Nixdorf	2006	936	369	172	0.18	0.18
Nokia	3596	6565	215	578	0.06	0.09
Olivetti	5286	5662	280	266	0.05	0.05
Philips	24377	35367	2026	2113	0.08	0.06
Racal	2092	2193	93	125	0.04	0.06
Schneider	3042	7390	329	798	0.11	0.11
Siemens	26894	55119	2903	4977	0.11	0.09
Thomson	10105	13277	653	762	0.06	0.06
Average	9173	14928	821	1177	0.09	0.08
s.e.	8529	15658	828	1344	0.1	0.09

In general, the technological specialisation of our firms, calculated with the Herfindhal index (H) and the specialisation ratio (SR), increased between the 1980s and the 1990s. The ranking of technologies remained mostly the same for the period 1970-83.[8]

Table 5 illustrates patent applications filed by the sample firms as a share of the world patent applications in selected technological fields during the period 1960-1996. These shares measure the technological performance of the sample firms. The performance in

[8] Herfindal index is a measure of diversification (sum of squared shares of each sector). The specialisation ratio represents the share of the largest sector in total patents. The RTA (revealed technological advantage) is an index of technological specialisation ((share of sector 'i' in the firm total patent)/(share of sector i in the world patents in all sectors)).

telecommunications is significant and stable over time. The performance in electrical devices and systems is also relatively positive and increasing over time. The performance in computers and semiconductors is poor and declining over time.[9]

Table 5: Shares of the sample firms in world patent applications to the US Patent Office

Spru Classes	1969-83	1984-90	1991-96
24 Telecommunications	0.261	0.219	0.274
30 Instrum.&control	0.191	0.170	0.213
28 Image&sound equipm.	0.152	0.100	0.134
26 Electrical devices&syst	0.207	0.226	0.257
27 Calculators, computers	0.125	0.070	0.104
14 General elect ind appar.	0.179	0.109	0.146
25 Semiconductors	0.175	0.079	0.141
13 Non electrical ind equip	0.171	0.185	0.159
16 Metallurgical equip	0.148	0.094	0.149
31 Misc metal products	0.135	0.136	0.188
33 Dentistry and surgery	0.159	0.202	0.181
18 Nuclear reaction	0.490	0.287	0.263
9 Materials	0.071	0.044	0.072
12 Apparatus for chem. etc	0.099	0.063	0.104

Agreements

The sectors where most EU-sponsored R&D agreements are concentrated are Software (sector 9), Telecommunications (sector 6), and Semiconductors (sector 10), which represent about 70% of total agreements.

The majority of non-sponsored agreements also centred on these sectors, with telecommunications (sector 6) emerging as the leading sector, followed by Computers (sector 8), Semiconductors (sector 10) and Software (sector 9) (see Table 2 above).

The commercial activities of the sample firms before 1984, proxied by the number of subsidiaries in 1983, appear to be more diversified than agreements. The largest four sectors - Transportation and Electrical Equipment (sector 3), Aircraft and Precision Instruments (sector 4), Telecommunication (sector 6), and Energy (sector 1) - account for about 48% of total subsidiaries in 1983. But, unlike agreements, a large share of subsidiaries was classified in miscellaneous sectors (14). This indicates that after 1984 the largest European electronics firms have focused their activities on fewer core sectors, even though during the period

[9] The share of patents in nuclear reaction is largely explained by the importance of energy activities for ABB, Siemens and Alcatel.

between 1984 and 1997 both non sponsored and EU-sponsored agreements have become more diversified over time (see Table 6).

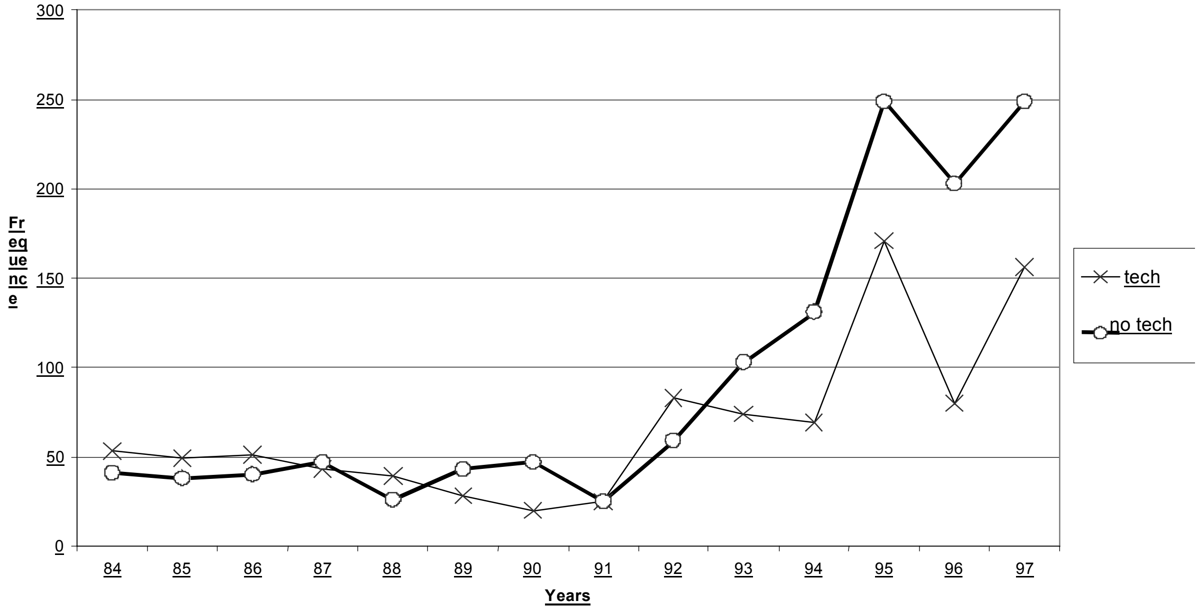
Table 6 Diversification of private and EU-sponsored agreements

	Herfindhal				Specialisation Ratio							
Year	**1984-90**		**1991-97**		**Private Agreements (AG)**				**EU Funded Agreements (Cordis)**			
	AG	**Cordis**	**AG**	**Cordis**	**84-90**	**Main Sector**	**91-97**	**Main Sector**	**84-90**	**Main Sector**	**91-97**	**Main Sector**
ABB	1.000	0.300	0.231	0.153	-	-	0.425	1	0.4	14	0.261	14
Alcatel	0.550	0.289	0.493	0.278	0.731	6	0.688	6	0.425	6	0.452	6
Bull	0.454	0.336	0.312	0.287	0.610	13	0.500	13	0.495	14	0.479	14
EMI	0.250	0.280	0.213	0.556	0.375	12	0.316	8	0.4	6	0.667	7
Ericsson	0.374	0.632	0.573	0.354	0.571	6	0.746	6	0.773	6	0.541	6
GEC	0.136	0.197	0.291	0.148	0.240	6	0.483	6	0.311	14	0.238	14
ICL	0.240	0.367	0.366	0.452	0.300	6	0.514	14	0.488	14	0.634	14
Nixdorf	0.497	0.355	0.643	0.338	0.607	14	0.786	13	0.529	14	0.509	14
Nokia	0.219	0.325	0.343	0.466	0.385	6	0.561	6	0.385	6	0.627	6
Olivetti	0.325	0.332	0.244	0.300	0.482	13	0.340	13	0.458	14	0.488	14
Philips	0.190	0.171	0.150	0.165	0.311	8	0.223	8	0.254	14	0.249	6
Racal	0.438	0.556	0.398	0.375	0.636	6	0.560	6	0.667	14	0.500	14
Schneider	1.000	0.556	0.333	0.148	-	-	0.500	11	0.667	6	0.231	6
Siemens	0.227	0.161	0.151	0.159	0.398	6	0.293	6	0.228	14	0.230	14
Thomson	0.228	0.239	0.190	0.187	0.371	14	0.269	6	0.351	14	0.262	6
Mean	0.409	0.340	0.329	0.291	0.463		0.480		0.455		0.425	
St.Err	0.269	0.141	0.148	0.132	0.153		0.173		0.155		0.163	

We classified non sponsored agreements in two categories: 'technological' and 'non technological' agreements. Each agreement is classified in the first category when it has some R&D content (e.g., joint development of a technology); therefore multidimensional agreements (e.g., joint development and production of a new product) are all classified as technological agreements. Non technological agreements include orders and contract received, marketing alliances etc.

Technological agreements represent a large share of total non sponsored agreements. Figure 2 shows the evolution of technological and non-technological agreements. It indicates quite clearly that technological and non-technological agreements are correlated over time. Moreover, the distribution of agreements across sectors is very similar between technological and non-technological agreements. However, non technological agreements were excluded from our analysis in order to make non sponsored agreements comparable with EU-sponsored agreements.

Figure 2: Total Agreements by Technological Content



Finally, as table 7 clearly shows, US and Japanese firms represent the most frequent partners of our firms in non sponsored alliances.

Table 7: Nationality of partners in non sponsored agreements

	Country						
Firm	USA	Japan	UK	France	Germany	Others	*Total*
ABB	18	5	5	0	0	54	82
Alcatel	51	11	6	9	7	41	125
Bull	47	16	6	17	7	39	132
EMI	18	2	6	2	0	6	34
Ericsson	93	11	7	4	4	72	191
GEC	22	1	28	14	3	24	92
ICL	32	4	20	5	7	30	98
Nokia	31	9	8	3	3	49	103
Olivetti	38	15	4	12	3	70	142
Philips	146	72	23	13	19	89	362
Racal	14	0	18	1	0	10	43
Schneider	3	0	2	2	0	6	13
Siemens	205	41	34	25	37	238	580
Nixdorf	18	2	1	0	3	26	50
Thomson	50	28	20	24	14	61	197
Total	786	217	188	131	107	815	2244
Shares	0.35	0.10	0.08	0.06	0.05	0.36	

4. The association between inter-firm alliances and firms' technological capabilities

A comparison between sponsored and non-sponsored agreements

This Section explores the effects of EU-sponsored and other non-sponsored agreements on the sample firms' technological capabilities within and across the 14 sectors discussed before. The dependent variable is the share of firm "i" in the world patents filed to the US Patent Office in sector "j", year t ($PAT_{i,j,t}=(P_{ij}/Pw_j)_t$).[10]

[10] It is worth noting that our independent variables are most probably endogenous. We do not have exogenous variables to instrument our regressors. However to our purposes here we are not interested in causal relationships. The association between technological capabilities and agreements is by itself an interesting result. We tested the Granger causality between patent share and various categories of agreements (sponsored, non sponsored, in the core sector and outside the core sector). The results show that lagged patents (1 year lag) do not have significant effects on patents whereas the effect of lagged agreements is significant.
Moreover, we do not analyse here the implications of technological perfomance (measured by patents) and the performance of the firm (e.s., sales growth). Preliminary inspections of our data show that there is a positive correlation between patent shares and sales growth of the sample firms. Although our dataset does not allow a rigorous analysis of this issue, earlier empirical works show that technological activities (measured by R&D or patents) do have significant positive effects on firm economic performance (total factor productivity and market value) (Mansfield, 1968, Griliches, 1979; Hall, 1993). The literature on the management of innovation also

The reason why we use patent shares among other possible measures is that this is easy to interpret. However, we found a strong correlation between patent shares and other indicators. For instance, the Pearson correlation between the patent share and the RTA index is high (0.88).

To analyse the effects of both AG and CORDIS agreements on the technological capabilities of the firm we distinguished between agreements in the firm's core sector and agreements outside the core sector. The core sector is defined here as the combination of the two most important sectors in terms of number of 1983 subsidiaries (at the three-digit SIC level). The distinction is based on the assumption that R&D agreements in the firm's core sectors reveal a strategy of incremental competence development along the line of its basic capabilities. By contrast, R&D agreements outside the core business indicate a strategy of competence diversification, which can be either offensive or defensive. For instance, a firm like Olivetti during the 1990s has tried to recover from a serious crisis by restructuring and diversifying its activities.

Patent shares were regressed on the following set of (lagged) explanatory variables:

- AG = Private agreements in the core sectors
- CO= CORDIS agreements in the core sectors
- OTHAG= Private agreements outside the core sectors
- OTHCO= CORDIS agreements outside the core sectors
- PATPERC= Patent Share of sector "j" in firm "i" 1983 patent stock
- RDCORE= annual R&D Expenditures in the core sectors (total R&D expenditures times the annual share of patents in the core sector).
- LOGSALES= Log of firm's sales

We tested the following econometric model

$$PAT_{i,j,t+1} = \beta_1 AG_{i,t} + \beta_2 CO_{i,t} + \beta_3 OTHAG_{i,t} + \beta_4 OTHCO_{i,t} + \beta_5 RDCORE_{i,t} + \beta_6 LOGSALES_{i,t} + \beta_7 PATPERC_{i,j} + \varepsilon_{i,t} \qquad (4.1)$$

shows the importance of technological capabilities on firms' economic performance (e.g., Prahalad and Hamel, 1990).

This is a panel data model of 2,940 observations (14 years, 15 firms and 14 sectors), with the PATPERC variable capturing the fixed firm effects. Note that, unlike PATPERC, RDCORE varies over time. Preliminary F-tests rejected the hypothesis of time fixed effects while the Hausman test rejected the presence of random effects.[11]

Table 8 shows the results of the regression analysis. The main effects of the regressors can be summarised as follows.

Table 8: The effects of sponsored and non-sponsored agreements on technological performance

R Square	Adj. R Square	Std. Error
.906	.904	3,113E-03

Coefficients

Regressor	B	Std. Error	t	p-value
LOGSALES	2.711	1.892	1.433	0.152
AG	1.081	0.803	1.346	0.178
OTHAG	3.238	0.855	3.786	0.000
CO	1.134	0.708	1.601	0.109
OTHCO	0.957	0.710	1.349	0.177
PATHPERC	1.004	0.068	14.776	0.000
RDCORE	1.556	0.771	2.018	0.044

1. The EU sponsored agreements (in the core or in non-core sectors), do not have any significant effects on the technological performance of the firm. These findings suggest that the largest European electronics firms do not participate in sponsored network to conduct new research or to acquire new technological capabilities. They have probably different purposes such as monitoring new technological startups, to strengthen previously established collaborative links, to test prototypes and try new applications of their existing technologies. It is worth noting that when we regressed CORDIS agreements on business diversification (measured by firm subsidiaries in different three-digit SIC sectors) we found significant positive effects. This reinforces the idea that EU sponsored agreements for these firms are probably a way to exploit their knowledge to entry new businesses rather than a way to explore new technological trajectories. Unfortunately our data do not allow seeing what the effects are for smaller firms which take part in R&D networks sponsored by the EU. Moreover, we cannot rule out that EU-sponsored agreements produce some positive effects on technological capabilities. Many EU-sponsored joint

[11] The Durbin-Watson tests rejects the hypothesis of serial correlation of residuals (DW=2.11).

R&D projects focus on the development of software technology, standards and "generic" architectures for the provision of services (e.g., multimedia services based on mobile communication platforms). The output of these projects is difficult to protect from imitation by means of patents. This could explain why the use of EU-sponsored agreements has weak technological effects measured by patents. Therefore, most probably, the participants to these EU sponsored projects have also improved their knowledge, but it is unlikely that these improvements result in patented inventions. For instance, many participants in TAP (Telematics Applications Programme) expected significant results from the collaboration in terms of new or improved telematics applications and systems. As a matter of fact, many demonstrators, prototypes, new and improved products, subsystems and services have been produced under this Programme. However, the main technological achievements of TAP are represented by standards, software and services while new (hardware) products made a negligible contribution to this Programme, as demonstrated by the insignificant share of patent applications and grants associated to its various projects (SPRU, 1999).

2. Private technological agreements have a significant and strong effect on technological performance, particularly those in non-core sectors. The estimates clearly indicate that private agreements outside the firm's core sectors increase the technological performance of the firm. We analysed the effects of agreements in specific sectors and found that some positive effects of private R&D agreements on the firms' technological performance can be clearly associated with technological complementarities and cross-fertilisation among sectors and technologies[12]. For instance, we found positive effects by agreements in 'telecommunications on general electrical industrial apparatus' technologies (class 3) which can be in part explained by the importance of 'energy storage' technologies (which belong to class 3) for mobile phones. This example shows that our firms set up links in a downstream sector (mobile phone) to build up capabilities in upstream technologies that are critical for the competitiveness in the downstream sector itself.
3. These results confirm the importance of cumulativeness and path-dependence in firms' technological activities, as showed by the strong effects of past technological activities (PATPERC and RDCORE) on present technological performance.
4. We should notice here that a large share of the variance in the regression is captured by the PATPERC variable. Precisely, R^2 falls to 0.34 when we omit PATPERC. However, the

significance of regressors is not affected by this omission. Moreover, our analysis is not centred on the R^2 of the equation by itself but to the fact that private agreements have an additional effects beyond that of internal accumulation of capabilities, measured by R&D expenditures and the pre-sample patent stock.[13] This indicates that both internal and external channels of knowledge accumulation produce significant effects on the technological performance of the firm.

Skill Complementarity

How can we explain the different effects of private and sponsored agreements on the technological performance of the sample firms? Why the technological complementarities and cross fertilisation discussed before did not show up in joint R&D sponsored by the EU? As mentioned above, it is possible that with sponsored agreements the sample firms pursue objectives different than the production of new technological knowledge (exploitation of existing technologies rather than exploration of new ones). Another possible explanation is that firms use sponsored agreements to develop knowledge which is not appropriable by means of patents - e.g., software. As a matter of fact, a large share of EU-sponsored agreements concerns software technology. Their potential effects on the technological capabilities of the firm cannot be measured by our indicator. However, the analysis of the effects of EU-sponsored agreements in software reveals that these agreements did not produce any effect on other related technologies such as telecommunications or computing. Furthermore, EU-sponsored agreements in other sectors (telecommunications and semiconductors) where the bulk of these agreements is concentrated do not produce any technological effect either.

A further explanation of the different effects observed is that private agreements offer greater opportunities to exploit the knowledge spillovers and technological complementarities compared with sponsored agreements. These opportunities in turn should arise from a greater degree of complementarity among the partners. The implications of competence complementarity for the outcome of joint R&D has been discussed at length in the literature (see, for example, Teece, 1992). When competence complementarity is high partners tend to

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[12] The estimates of these effects are not reported in this paper but can be provided by the authors.

[13] We tried different specifications of some independent variables (e.g., SALES, SALES**2 and PATPERC**2) to account for possible scale and specialisation effects. The results showed in the tables are robust to alternative specifications of SALES while the effect of PATPERC**2 is not significant.

share their capabilities and this in turn favours "synergy" and innovation. By contrast, partners with similar technological capabilities tend to sign agreements which aim primarily to share R&D costs rather than to exploit "synergy". This reduces the potential innovative outcome of these agreements (Sakakibara, 1997).

Complementarity can be defined on a purely technological ground, as in the case of two partners with co-specialised technical capabilities (e.g., software and semiconductors). Complementarity can be defined in a broader sense by including non technological capabilities. For instance, the agreements between a firms specialised in semiconductors and another one with expertise in system integration and assembling of electronic equipment for a specific market niche.

Our data do not allow to test directly the hypothesis of complementarity, but we can try an indirect test by assuming that the level of complementarity (broadly defined) in agreements between European and non EU firms (US and Japanese) is greater than that in agreements among European partners. A basic source of complementarity between many European firms and their US and Japanese counterparts is simply represented by their different specialisation - marketing and servicing capabilities in the European markets Vs. technological and organisational capabilities in semiconductors or computers respectively. Another source of complementarity between EU and non European firms is mostly technical. An example of such complementarity is represented by the strategic alliance between Ericsson, the world's largest supplier of switching systems, and Tandem Computers, a market leader in open parallel processing reliable client server solutions and enterprise networks. The deal signed in 1995 enabled Ericsson to integrate Tandem's Unix platform into its future products. The agreement also concerned the incorporation of present and future Tandem computing solutions for Unix systems into Ericsson's future AXE solutions.

Since EU-sponsored agreements do not involve extra-European partners we have to focus our analysis on private agreements and distinguish between infra-European agreements and extra-European ones. The latter are defined as those alliances with at least one extra-European partner.

Over 66% of private alliances in our dataset include two partners, 23% three partners and 11% more than three partners. 59% of agreements with two partners, 63% of agreements with three partners and 73% of agreements with more than three partners respectively are extra-European.

We regressed the same dependent variable analysed before (PAT) with the following lagged regressors:

- RDCORE= R&D Expenditure in the core sector
- LOGSALES= Log sales of firm
- EUAG = Intra-EU private agreements in the core sectors
- EUNOAG = Intra-EU private agreements outside the core sector
- WAG = Extra-EU private agreements in the core sectors
- WNOAG = Extra-EU private agreements outside the core sectors
- PATPERC= Patent Share of Firm "i " in sector "j" calculated with 1983 patent stock

The model tested is the following:

$$PAT_{i,j,t+1}= \beta_1 EUAG_{i,t}+\beta_2 EUNOAG_{i,t}+\beta_3 WAG_{i,t}+\beta_4 WNOAG_{i,t} +\beta_5 RDCORE_{i,t}+\beta_6 LOGSALES_{i,t}+\beta_7 PATPERC_{i,j} + \varepsilon_{i,t} \qquad (4.2)$$

The results of the regressions reported in Table 9 confirm that extra-European agreements signed outside the core sector of the firm have a positive and significant effect on technological performance. These findings support the hypothesis that the level of complementarity among partners drives the effect of non-sponsored agreements on the technological performance of the firm.

Table 9: The effects of agreements with non-EU partners

R Square	Adj R Square	Std. Error
0.906	0.906	3,112E-03

Coefficients

Regressor	Beta	s.e.	t	p-value
RDCORE	1.272	0.616	2.065	0.039
LOGSALES	6.800	4.149	1.639	0.101
PATHPERC	1.004	0.007	151.330	0.000
EUAG	3.038	2.126	1.429	0.153
WNOAG	4.748	1.129	4.206	0.000
WAG	5.160	7.748	0.666	0.505
EUNOAG	1.098	1.112	0.987	0.324

5. Conclusions and policy implications

This paper analyses the effects of inter-firm collaboration on the technological capabilities measured by the patent applications of the largest European electronics firms between 1984 and 1997.

During this period EU firms have continued to rely on non-EU partners, especially North Americans, despite the rising number of EU-sponsored agreements in the same period. This suggests that European firms have more incentives to set up links outside the EU in order to gain access to complementary capabilities and resources (such as technology) which are mostly possessed by US and Japanese firms.

The regression analysis shows that EU-sponsored agreements have insignificant effects on technological capabilities.

By contrast, non-sponsored agreements have significant effects on firm' capabilities in many technological fields. In particular, agreements with extra European partners signed outside the core sector show significant effects on the technological capabilities of the sample firms.

How to explain these differences in the effects on the technological capabilities of the firms?

The positive effects of agreements with US and Japanese firms outside the firm's core sector suggests that the complementarity of capabilities between partners is probably a main factor at work. By complementarity we mean the presence of co-specialised technical, organisational or commercial capabilities, e.g. the knowledge of a generic technology such as microelectronic and the expertise in specific applications such as medical equipment or industrial automation equipment.

Why non-sponsored agreements among EU firms do not produce in general significant effects on the technological capabilities of the firm? As in the case of sponsored agreements, the main reason is probably represented by a lack of complementarity among partners. This does not imply obviously that all non sponsored agreements within the group of European firms suffer from a lack of complementarity. Consider, for instance, the agreement signed in 1997 by Siemens and EDAP Technomed, a French company specialised in "minimally invasive urological therapy". This is an example of non-sponsored agreement centred on the exploitation of skill complementarity. With this alliance the two firms agreed to joint develop a new urological platform for non invasive diagnosis, combing EDAP’s capabilities in minimally invasive medical therapies and Siemens’ experience in the field of medical equipment and image processing. As a result of this agreement in 1998 these two firms were jointly granted a patent from the US Patent Office concerning a “Method and apparatus for ultrasound tissue therapy”. Our results however suggest that this example is an exception more than the rule for non sponsored agreements between European firms.

According to our analysis then two European electronic firms which are identical in all respects (size, past technological activities etc.) except for the number of Extra-European agreements, should differ in their technological performance (the firm with a larger number of agreements should have a larger expected technological performance).

We should warn about some important limitations of our results. One of such limitation is that our data do not allow observing directly the technological outcome of each agreement. Neither we can distinguish across agreements of different "quality", that is agreements with different technological potentiality or a different degree of complementarity between partners. Moreover, due to the selection bias of our sample (the largest electronics European firms), we cannot draw any general conclusion about the effects of EU R&D policies on firms' technological performance. It is important to remember that the size of EU funds allocated to joint R&D is very limited compared with the scale of R&D of the largest European electronics firms. For example, Esprit funds for the period 1984-1994 have an order of magnitude similar to the R&D expenditures of Siemens in 1990. Moreover, the cumulative contribution of Esprit to Bull in the 1980s was about 5% of its total R&D expenditures (Mytelka, 1992 and 1995). Probably, EU-sponsored programmes are more relevant to SMEs and future empirical should collect more careful information on the implications of these programmes for SMEs. By the same token, our analysis does not account for the possible effects of EU programmes on users since we only focus on the generation of technology. If anything, our analysis indicates that

EU policies show limited effects on the production of new patented technology. This may reflect particular problems with the organisation of EU projects in terms of IPR arrangements.

The overall picture emerging from these results suggests that the most successful strategy of technological learning for large European electronics firms draws on both internal accumulation of capabilities (as showed by the importance of R&D and past patent applications) and the acquisition of new knowledge from complementary (and technologically strong) partners. The evidence presented in this paper suggests that the European Commission should reconsider carefully its policies towards joint R&D and possibly adopt a more “outward-looking” approach by allowing the participation of non European firms in EU programmes. It is worth noting that even though non-European firms are allowed to participate in EU programmes, the small number of US and Japanese firms involved in these programmes suggests that extra-EU firms have not enough incentives to join EU R&D Programmes. And this may be one of the reasons of the poor technological output of these programmes.

We cannot conclude that the EU policies have distorted the patterns of alliances of the European electronics firms since these have been involved in a great deal of intra-European collaboration outside the EU umbrella. However, it is possible that the EU policies have strengthened the network of intra-European collaboration and therefore reinforced a pattern of alliances which is not optimal in terms of the accumulation of technological capabilities.

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APPENDIX

Table A.1. SPRU patent classes

1 Inorganic Chemicals
2 Organic Chemicals
3 Agricultural Chemicals
4 Chemical Processes
5 Hydrocarbons, mineral oils, fuels and igniting devices
6 Bleaching Dyeing and Disinfecting
7 Drugs and Bioengineering
8 Plastic and rubber products
9 Materials (inc glass and ceramics)
10 Food and Tobacco (processes and products)
11 Metallurgical and Metal Treatment processes
12 Apparatus for chemicals, food, glass etc.
13 General Non-electrical Industrial Equipment
14 General Electrical Industrial Apparatus
15 Non-electrical specialized industrial equipment
16 Metallurgical and metal working equipment
17 Assembling and material handling apparatus
18 Induced Nuclear Reactions: systems and elements
19 Power Plants
20 Road vehicles and engines
21 Other transport equipment (exc. aircraft)
22 Aircraft
23 Mining and wells machinery and processes
24 Telecommunications
25 Semiconductors
26 Electrical devices and systems
27 Calculators, computers, and other office equipment
28 Image and sound equipment
29 Photography and photocopy
30 Instruments and controls
31 Miscellaneous metal products
32 Textile, clothing, leather, wood products
33 Dentistry and Surgery
34 Other - (Ammunitions and weapons, etc.)

Table A.2 : Sample firms' most important technologies

SPRU Classes	Description
24	Telecommunications
30	Instruments and controls
28	Image and sound equipment
26	Electrical devices and systems
27	Calculators, computers
14	General Electrical Industrial Apparatus
25	Semiconductors
13	General Non-electrical Industrial Equipment
4	Chemical Processes
16	Metallurgical and metal working equipment
18	Induced Nuclear Reactions
33	Dentistry and Surgery
31	Miscellaneous metal products
9	Materials (inc glass and ceramics)

Table A.3: Sectors resulting from the cluster analysis (agreements)

Sectors	Description
1	Energy
2	Metalworking products and machinery
3	Transportation and Electrical Equipment
4	Aircraft and Precision Instruments
5	Broadcasting, Satellite Comm. and Electronic Equip.
6	Telecommunication
7	Consumer Electronics
8	Office and Computing Machines
9	Computer Services
10	Semiconductors
11	Drugs, Pharmaceuticals and Medical Instruments
12	Chemicals
13	Special Machinery, Plastics and Non Ferrous Metal
14	Miscellaneous

Table A.4: Concordance between industrial clusters and 3 digit SIC sectors

Cluster	N° links	SIC Code	Description
1	312	491	Electric Utilities
1	196	162	Bridge and Tunnel Contruction
1	122	492	Gas Utilities
1	116	131	Crude Petroleum and Natural Gas
1	98	891	Engineering and Architectural Svcs
1	98	291	Petroleum
1	58	110	Coal
1	56	361	Electrical Power Equipment
1	16	458	Air Transport Facilities
2	222	331	Primary Iron and Steel
2	56	354	Metalworking Machinery
2	2	332	Iron and Steel Foundary
3	406	371	Motorvehicles and Parts
3	108	369	Electrical and Electronics NEC
3	80	671	Financial Holding Company
3	60	362	Electric Industrial Equip.
3	58	731	Advertising
3	46	301	Tires and Tubes
3	28	351	Engines and Turbines
3	24	364	Electric Lighting and Wiring
3	22	358	Services Industry Machines
3	16	349	Fabricated Metal Products NEC
3	12	495	Pollution Control
3	8	336	Nonferrous Foundries
3	8	326	Ceramics and Related Products
4	116	372	Aircraft and Parts
4	100	382	Measuring and Control Instruments
4	92	383	Optical and Analytical Instruments
4	74	508	Machinery Equip. And Supplies Whsle
4	46	506	Electrical Goods Whsle
4	44	335	Non Ferrous Mill Products
4	42	356	General Industry Machinery
4	10	300	Rubber and Plastic Products
4	8	343	Plumbing and Heating Equip.
5	340	483	Radio and TV Broadcasting
5	296	360	Electical and Electronic Equip.
5	276	386	Photographic Equip. And Supplies

5	148	484	Satellite Communication
5	74	376	Missiles, Space Vehicles and Parts
5	44	998	Diversified Company
5	30	380	Instruments and Related Products
5	20	573	Radio, TV, Music, Electronics Store
5	16	454	Commercial Space Services
5	16	374	Railroad Equip.
5	12	348	Ordnance and Accessories
5	8	910	Public Administration and Finance
5	4	381	Engineering and Scientific Instr
5	2	370	Transport Equip.
5	2	334	Secondary Nonferrous Metal
5	2	379	Transport Equip. NEC
6	932	481	Telecommunication
6	650	366	Communication Equip.
6	38	401	Railroads
6	32	480	Communications
6	26	322	Glass Containers
6	20	344	Fabricated Structural
6	4	494	Water Supply and Use
6	2	490	Electric Gas Utilities
7	266	365	Consumer Electronics
7	100	363	Household appliance
7	40	739	Business Services
7	34	519	Wholesalers NEC
7	16	373	Ship and Boat building
7	8	431	Mail Express and Services
7	2	824	Vocational Education
8	458	357	Office and Computing Machines
9	720	737	Computer Services
10	386	367	Electronic Components
11	546	283	Drugs and Pharmaceuticals
11	454	280	Chemicals and allied Products
11	134	384	Medical Instruments and Supplies
11	30	800	Health, Education and Welfare
11	22	851	Research and Development
11	16	299	Petroleum and Energy Products NEC
11	2	385	Ophthalmic Goods
11	2	738	Contract Packaging Services
12	294	286	Organic Chemicals
12	224	282	Plastics, Rubber, Fiber
12	108	281	Inorganic Chemicals
12	54	285	Paints and Allied Products
12	52	289	Misc Chemical Products
13	304	307	Plastic Products
13	114	355	Special Industry Machinery
13	108	333	Non Ferrous Metals
13	82	330	Metals
13	66	350	Machinery Ex-Electric
13	40	602	Commercial Banks
13	40	347	Metal Plating and Coating
13	32	781	Motion Picture and TV Production
13	30	394	Toys and Sporting Goods
13	24	260	Paper and Allied Products
13	22	220	Textile Mill Products
13	18	581	Eating Places
13	16	270	Printing and Publishing
13	4	154	Non Residential Bulding
13	4	375	Motorcycles and Bicycles

13	2	274	Publishing NEC
14	16	329	Misc Non Metallic Mineral Products
14	14	275	Commercial Printing
14	12	342	Cutlery Hand Tools and Hardware
14	4	783	Motion Picture Theatre
14	2	478	Bridge, Tunnel
14	1	199	Home Gardening
14	1	339	Metals Nec
14	1	149	Non Metal Minerals Nec
14	1	410	Local Intercity Transit
14	1	951	Regional Trade Group
14	1	930	Local Government
14	1	912	Executive Departments
14	1	890	Professional Services
14	1	769	Electric Motor Repair
14	1	605	Banking Related Services
14	1	572	Household Appliance Store
14	1	496	Steam Supply
14	1	833	Job and Vocational Services
14	1	470	Transport Services
14	1	762	Repair Services NEC
14	1	966	Fishery cooperatives
14	1	991	Business Method

Danish **R**esearch **U**nit for **I**ndustrial **D**ynamics

The Research Programme

The DRUID-research programme is organised in 3 different research themes:

- The firm as a learning organisation

- Competence building and inter-firm dynamics

- The learning economy and the competitiveness of systems of innovation

In each of the three areas there is one strategic theoretical and one central empirical and policy oriented orientation.

Theme A: The firm as a learning organisation

The theoretical perspective confronts and combines the resource-based view (Penrose, 1959) with recent approaches where the focus is on learning and the dynamic capabilities of the firm (Dosi, Teece and Winter, 1992). The aim of this theoretical work is to develop an analytical understanding of the firm as a learning organisation.

The empirical and policy issues relate to the nexus technology, productivity, organisational change and human resources. More insight in the dynamic interplay between these factors at the level of the firm is crucial to understand international differences in performance at the macro level in terms of economic growth and employment.

Theme B: Competence building and inter-firm dynamics

The theoretical perspective relates to the dynamics of the inter-firm division of labour and the formation of network relationships between firms. An attempt will be made to develop evolutionary models with Schumpeterian innovations as the motor driving a Marshallian evolution of the division of labour.

The empirical and policy issues relate the formation of knowledge-intensive regional and sectoral networks of firms to competitiveness and structural change. Data on the structure of production will be combined with indicators of knowledge and learning. IO-matrixes which include flows of knowledge and new technologies will be developed and supplemented by data from case-studies and questionnaires.

Theme C: The learning economy and the competitiveness of systems of innovation.

The third theme aims at a stronger conceptual and theoretical base for new concepts such as 'systems of innovation' and 'the learning economy' and to link these concepts to the ecological dimension. The focus is on the interaction between institutional and technical change in a specified geographical space. An attempt will be made to synthesise theories of economic development emphasising the role of science based-sectors with those emphasising learning-by-producing and the growing knowledge-intensity of all economic activities.

The main empirical and policy issues are related to changes in the local dimensions of innovation and learning. What remains of the relative autonomy of national systems of innovation? Is there a tendency towards convergence or divergence in the specialisation in trade, production, innovation and in the knowledge base itself when we compare regions and nations?

The Ph.D.-programme

There are at present more than 10 Ph.D.-students working in close connection to the DRUID research programme. DRUID organises regularly specific Ph.D-activities such as workshops, seminars and courses, often in a co-operation with other Danish or international institutes. Also important is the role of DRUID as an environment which stimulates the Ph.D.-students to become creative and effective. This involves several elements:

- access to the international network in the form of visiting fellows and visits at the sister institutions
- participation in research projects
- access to supervision of theses
- access to databases

Each year DRUID welcomes a limited number of foreign Ph.D.-students who wants to work on subjects and project close to the core of the DRUID-research programme.

External projects

DRUID-members are involved in projects with external support. One major project which covers several of the elements of the research programme is DISKO; a comparative analysis of the Danish Innovation System; and there are several projects involving international co-operation within EU's 4th Framework Programme. DRUID is open to host other projects as far as they fall within its research profile. Special attention is given to the communication of research results from such projects to a wide set of social actors and policy makers.

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